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PRELIMINARY SEISMOLOGICAL ANALYSIS OF G 29-38

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Abstract

G 29-38 is a cool pulsating DA white dwarf with a series of modes from 110 s to over 1000 s found by Kleinman et al. (1996, ApJ, in preparation). Kleinman et al. (1996) present suggestive evidence that most of the modes they see are $\ell = 1$ modes, but they could not prove this assertion with their data. The large number of modes (10 to 20) present in G 29-38 gives us hope that we can constrain the mode structure in the manner that Bradley & Winget (1994, ApJ, 430, 850) use for the DBV GD 358. Here, we try to match the observed data with periods predicted from models similar to those of Bradley (1996, ApJ, 468, in press).

We present results of our attempts to find a seismological fit to G 29-38 using the data of Kleinman et al. and look for a model that identifies most of the observed modes as $\ell = 1$ modes. G 29-38 has a discrepancy between the spectroscopically favored mass of about $0.70M_{\odot}$ and the parallactic mass of about $0.80M_{\odot}$. We attempt to find models that are consistent with either mass determination and see if we can place constraints on the hydrogen layer mass with these assumptions. We also look for models that have hydrogen layer masses that have hydrogen layer masses near $10^{-4}M_{\star}$, consistent with the value Clemens (1994, Ph.D. dissertation, U. Texas) suggests for the hotter DAV stars. We also look to see if other combinations of stellar mass and hydrogen layer mass are consistent with the observed data and explore their consequences.

PRELIMINARY ASTEROSEISMOLOGY OF G 29-38

by

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G 29-38 and the ZZ Ceti Stars

1. G 29-38 is the first cool pulsating DA white dwarf to show a large number of modes.
2. The short period modes have periods similar to what we expect when we extrapolate from the periods of the hotter ZZ Ceti stars.
3. G 29-38 is about 10^8 yr older than the hottest ZZ Ceti stars. Are there any differences?
4. The spectroscopic mass ($0.69M_{\odot}$) disagrees with the mass implied by trigonometric parallax ($0.8M_{\odot}$).
5. G 29-38 has a number of temperature and surface gravity determinations.
 - $T_{\text{eff}} = 12,600K$; $\log g = 8.1$; McGraw (1979).
 - $T_{\text{eff}} = 11,400K$; $\log g = 8.0$; Greenstein (1982).
 - $T_{\text{eff}} = 11,600K$; $\log g = 7.9$; Weidemann & Koester (1984).
 - $T_{\text{eff}} = 12,100K$; $\log g = 8.0$ (assumed); Wesemael et al. (1986).
 - $T_{\text{eff}} = 11,600K$; $\log g = 8.1$; Daou et al. (1990).
 - $T_{\text{eff}} = 11,400K$; $\log g = 8.0$ (assumed); Kepler & Nelan (1993).
 - $T_{\text{eff}} = 11,820K$; $\log g = 8.14$; Bergeron et al. (1995).
6. The most recent parallax value is $0.''0734 \pm 0.''0040$.

Properties of ZZ Ceti White Dwarfs

1. ZZ Ceti white dwarfs lie between $\sim 13,000$ K and $11,000$ K.
2. Pulsation driving comes mainly from the κ, γ mechanism operating in the hydrogen partial ionization zone (Bradley & Winget 1994; Fontaine et al. 1994).
3. Observed light variations are due to changes in the surface temperature distribution (Robinson, Kepler, & Nather 1982).
4. ZZ Ceti stars appear to be otherwise normal DA white dwarfs that happen to be passing through an instability strip, so what we learn about pulsators should apply to almost all DA white dwarfs.
5. DAs comprise about 80 % of all known white dwarfs, so they dominate in studies of the bulk properties of white dwarfs, such as the luminosity function and mean white dwarf mass.

Description of Seismological Fits

At present, no one model fits all of the observed periods.

$\leq 0.60M_{\odot}$ • These models do not fit the 110s period, except possibly as the $\ell = 2, k = 1$ mode.

- Good models tend to fit either the low period (< 600 s) or longer period (> 500 s) modes well, but not both. The mode at 284s fits well, because I demanded this.
- The best looking fit is at $M_H \sim 10^{-5}M_{\star}$.
- The seismological distance is 5 to 6 pc farther than trig. parallax calls for.

$\approx 0.70M_{\odot}$ • These models have $\log g \approx 8.17$, very close to the observational value of 8.14.

- No model matches the 110s or 237s modes and most fail at 177s.
- Some models do well between 400 to 800s and the hydrogen layer mass tends to lie between $10^{-4}M_{\star}$ and $10^{-6}M_{\star}$.
- The seismological and spectroscopic distance is about 3 pc too high.

$\approx 0.75M_{\odot}$ • The seismological $\log g \approx 8.26$ is a bit higher than model atmospheres predict.

- However, models with $M_H \approx 5 \times 10^{-7}M_{\star}$ fit about the best of any model to date.

Period Spacings for G 29-38 versus a model

Table 1: Comparison of Observed Periods

Object	G 29-38	G 226-29	L 19-2	BPM 31594	G 117-B15A	HL Tau 76
T_{eff} (K)	11,820	12,460	12,100	11,540	11,620	11,440
$\log g$	8.14	8.29	8.21	8.11	7.97	7.89
$M_{\star}/M_{\odot}$	0.69	0.79	0.74	0.67	0.59	0.55
Period (s)						
	110	109	118			
	177		192		215	
	237				270	
	284 *				304	
	355		350			360 ?
	400 *			402		383
	—					
	500					494
	552					541
	610 *					597
	649					
	678 *					665
	730					691 ?
	771					
	809					799 ?
	860					
	894					
	915					

Table 2: Comparison of G 29-38 to Models

Object	G 29-38	ch751057	y751057	ch753557	ch751056
T_{eff} (K)	11,820	11,830	12,100	11,910	11,620
$\log g$	8.14	8.26	8.26	8.26	8.26
$M_{\star}/M_{\odot}$	0.69	0.75	0.75	0.75	0.75
$M_{\text{H}}/M_{\star}$		5×10^{-7}	5×10^{-7}	5×10^{-7}	10^{-6}
$M_{\text{He}}/M_{\star}$		10^{-2}	10^{-2}	5×10^{-3}	10^{-2}
dist. (pc)	13.6	15.3	15.2	15.6	15.3
Period (s)					
	110	2,1 109	2,1 109	2,1 112	2,1 112
	177	1,1 184	1,1 184	1,1 191	1,1 181
	—	1,2 198	1,2 199	1,2 201	1,2 189
	237	1,3 238	1,3 [REDACTED]	1,3 233	1,3 238
	284 *	1,4 280	1,4 282	1,4 287	1,4 283
	355	1,5 351	1,5 351	1,5 354	1,5 [REDACTED]
	400 *	1,6 392	1,6 393	1,6 405	1,6 394
	—	1,7 436	1,7 431	1,7 430	1,7 437
	—	1,8 471	1,8 471	1,8 481	1,8 458
	500	1,9 507	1,9 508	1,9 [REDACTED]	1,9 502
	552	1,10 [REDACTED]	1,10 [REDACTED]	1,10 [REDACTED]	1,10 564
	610 *	1,11 606	1,11 617	1,11 607	1,11 [REDACTED]
	649	1,12 [REDACTED]	1,12 647	1,12 [REDACTED]	1,12 [REDACTED]
	678 *	1,13 684	1,13 683	1,13 691	1,13 680
	730	1,14 728	1,14 730	1,14 728	1,14 [REDACTED]
	771	1,15 [REDACTED]	1,15 763	1,15 [REDACTED]	1,15 [REDACTED]
	809	1,16 [REDACTED]	1,16 815	1,16 806	1,16 [REDACTED]
	860	1,17 851	1,17 865	1,17 857	1,17 [REDACTED]
	894	1,18 891	1,18 900	1,18 902	1,18 [REDACTED]
	915	1,19 [REDACTED]	1,19 [REDACTED]	1,19 [REDACTED]	1,19 [REDACTED]

- The best model says the 110s mode is $\ell = 2, k = 1$ and comes within at least 10σ of all modes but the 552s one out to 900s.
- The seismological distance is 15.2 pc, about 2σ higher than the parallax value of 13.6 pc.

$\approx 0.80M_{\odot}$ • The distance is still a bit high, and so is the model surface gravity.

- When $M_H \approx 10^{-4}M_{\star}$, the $\ell = 1, k = 1$ period is 110s.
- Fits to the other periods are so-so, and models with $M_H \approx 5 \times 10^{-5}M_{\star}$ do best.
- Model $\log g \approx 8.32$ and distance is just under 15 pc.

$\approx 0.85M_{\odot}$ • These models have luminosities matching that from trig. parallax, at the expense of $\log g \approx 8.40$, a full 0.25 dex above spectra.

- Only select parts of the period spectrum fit, suggesting the mean period spacing is too short.
- I also don't do well at matching the 110s period here.